Hydropower

2002 Facts at a Glance

Classification: Renewable Energy Source

Percent of energy produced in US:	**3.7% (2.6 Q)**
Percent of energy consumed in US:	**2.7% (2.6 Q)**

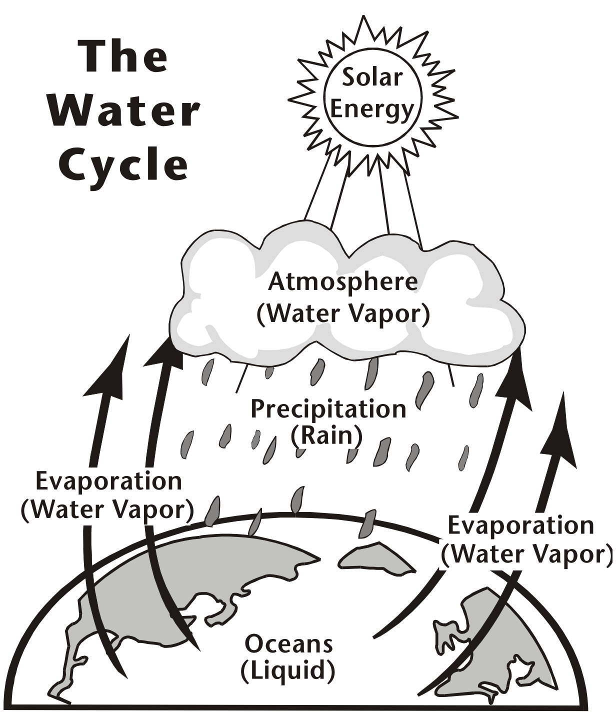
Major use: electricity

What Is Hydropower?

Hydropower (from *hydro* meaning water) is energy that comes from the force of moving water.

The fall and flow of water is part of a continuous natural cycle. The sun draws moisture up from the oceans and rivers, and the moisture then condenses into clouds in the atmosphere. The moisture falls as rain or snow, replenishing the oceans and rivers. Gravity drives the water, moving it from high ground to low ground. The force of moving water can be extremely powerful.

Hydropower is called a **renewable** energy source because it is replenished by snow and rainfall. As long as the rain falls, we won't run out of this energy source.



History of Hydropower

Hydropower has been used for centuries. The Greeks used water wheels to grind wheat into flour more than 2000 years ago. In the early 1800s, American and European factories used the water wheel to power machines.

The water wheel is a simple machine. The water wheel picks up flowing water in buckets located around the wheel. The weight of the water causes the wheel to turn. Water wheels convert the kinetic energy (energy pertaining to motion) of water to mechanical energy. The mechanical energy can then be used to grind grain, drive sawmills, or pump water.

In the late 19th century, the force of falling water was used to generate electricity. The first hydroelectric power plant was built at Niagara Falls in 1879. In the following decades, many more hydroelectric plants were built. At its height in the early 1940s, hydropower provided 33 percent of this country's electricity.

By the late 1940s, the best sites for big dams had been developed. Inexpensive fossil fuel plants also entered the picture. At that time, plants burning coal or oil could make electricity more cheaply than hydro plants. Soon they began to underprice the smaller hydroelectric plants.

It wasn't until the oil shocks of the 1970s that people showed a renewed interest in hydropower.

Hydro Dams

It's easier to build a hydro plant where there is a natural waterfall. That's why the first hydro plant was built at Niagara Falls. Dams, which are artificial waterfalls, are the next best way.

Dams are built on rivers where the terrain will produce an artificial lake or **reservoir** above the dam. Today there are about 80,000 dams in the United States, but only three percent have power-generating hydro plants. Most dams are built for flood control and irrigation, not electric power generation.

A dam serves two purposes at a hydro plant. First, a dam increases the **head** or height of a waterfall. Second, it controls the flow of water. Dams release water when it is needed for electricity production. Special gates called **spillway gates** release excess water from the reservoir during heavy rainfalls.

Hydropower Plants

As people discovered centuries ago, the flow of water represents a huge supply of kinetic energy that can be put to work. Water wheels are useful for generating mechanical energy to grind grain or saw wood, but they are not practical for generating electricity. Water wheels are too bulky and slow.

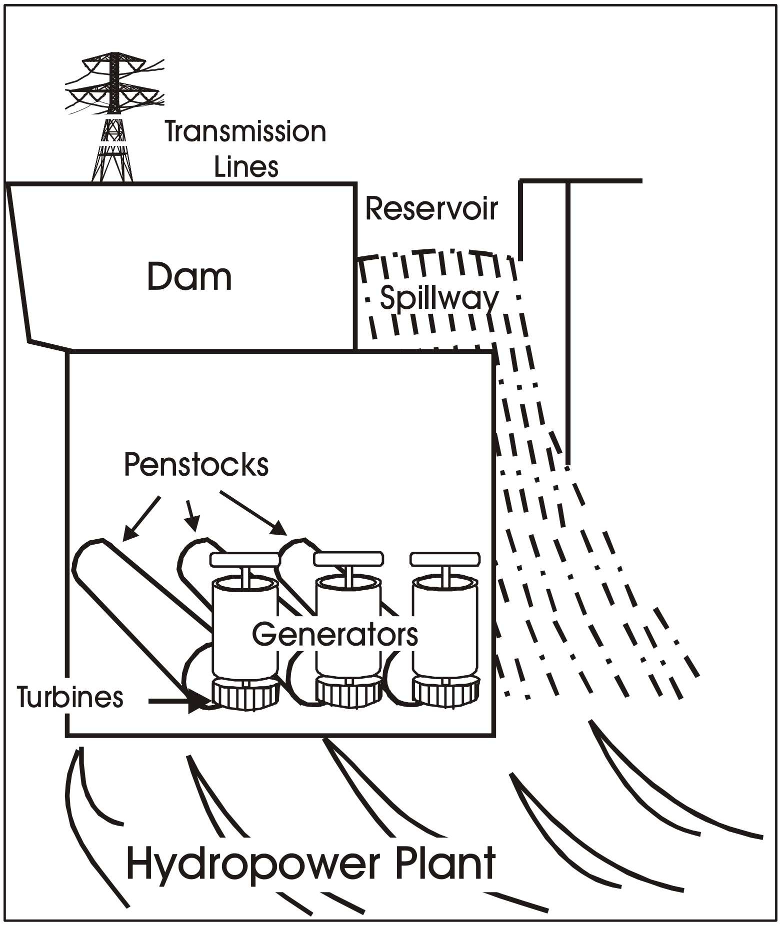
Hydroelectric plants are different. They use modern turbine generators to produce electricity, just as thermal (coal, oil, nuclear) power plants do.

How a Hydro Plant Works

A hydro plant uses the force of falling water to make electricity. A typical hydro plant is a system with three parts:

- an electric plant where the electricity is produced.
- a dam that can be opened or closed to control water flow.
- a reservoir (artificial lake) where water can be stored.

To make electricity, a dam opens its gates to allow water from the reservoir to flow through a large tube called a **penstock**. At the bottom of the penstock, the fast-moving wa-



ter spins the blades of a turbine. The turbine is connected to a generator to produce electricity. The electricity is then transported via huge transmission lines to a local utility company.

Head and Flow

The amount of electricity that can be generated at a hydro plant is determined by two factors: head and flow. **Head** is how far the water drops. It is the distance from the highest level of the dammed water to the point where it goes through the power-producing turbine.

Flow is how much water moves through the system. The more water moving through a system, the higher the flow. Generally, a **high-head plant** needs less water flow than a **low-head plant** to produce the same amount of electricity.

Storing Energy

One of the biggest advantages of a hydro plant is its ability to store energy. The water in a reservoir is, after all, stored energy.

Water can be stored in a reservoir and released when needed for electricity production. During the day when people use more electricity, water can flow through a plant to generate electricity. Then, during the night when people use less electricity, water can be held back in the reservoir. Storage also makes it possible to save water from winter rains for summer generating power, or to save water from wet years for generating electricity during dry years.

Pumped Storage Systems

Some hydro plants use pumped storage systems. A pumped storage system operates much as a public fountain does. The same water is used again and again.

At a pumped storage hydro plant, flowing water is used to make electricity and then stored in a lower pool. Depending on how much electricity is needed, the water may be pumped back to an upper pool. Pumping water to the upper pool requires electricity so hydro plants usually use pumped storage systems only when there is a big demand for electricity.

Pumped hydro is the most reliable energy storage system used by American electric utilities. Coal and nuclear power plants have no energy storage systems. They must turn to expensive gas and oil-fired generators when people demand lots of electricity. They also have no way to store any extra energy they might produce during normal generating periods.

Hydro Production

How much electricity do we get from hydropower today? Depending on the amount of rainfall, hydro plants produce from five to ten percent of the electricity produced in this country (10 percent in 1997, 5.6 percent during the protracted drought of 2001). In Oregon and Washington, hydropower supplies over 85 percent of the electricity each year.

Today, there are about 75 million kilowatts of hydro generating capacity in the United States. That's equivalent to the generating capacity of 70 large nuclear power plants. The biggest hydro plant in the U.S. is located at the Grand Coulee dam on the Columbia River in northern Washington.

The United States also gets some hydropower from Canada. Some New England utilities buy this imported electricity.

What does the future look like for hydropower? The best sites for hydropower dams have already been developed so the development of big hydro plants is unlikely.

Existing plants could be enlarged to provide additional generating capacity. Plus, many flood-control dams not equipped for electricity production could be outfitted with generating equipment. The Federal Energy Regulatory Commission estimates 60 thousand megawatts of additional generating capacity could be developed in the United States.

Hydropower for Baseload Power

Demand for electricity is not steady; it goes up and down. People use more electricity during the day when they are awake and using electrical appliances, and less at night when they are asleep. People also use more electricity when the weather is very cold or very hot.

Electric utility companies have to produce electricity to meet these changing demands. Baseload power is the electricity that utilities have to generate all the time. For that reason, baseload power should be cheap and reliable. Hydropower meets both these requirements. Generating electricity with hydropower is the cheapest way to generate electricity in the U.S., and the fuel supply—flowing water—is always available.

Hydro plants are more energy efficient than most thermal power plants, too. That means they waste less energy to produce electricity. In thermal power plants, a lot of energy is lost as heat. Hydro plants also run 85 percent of the time, about 50 percent more than thermal plants.

Economics of Hydropower

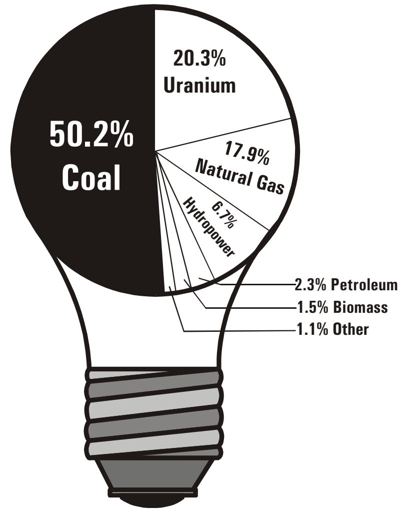
Hydropower is the cheapest way to generate electricity today. No other energy source, renewable or nonrenewable, can match it. Today, it costs about one cent per kWh (kilowatt-hour) to produce electricity at a typical hydro plant. In comparison, it costs coal plants about four cents per kWh and nuclear plants about two cents per kWh to generate electricity.

Producing electricity from hydropower is cheap because, once a dam has been built and the equipment installed, the energy source—flowing water—is free.

Hydropower plants also produce power cheaply due to their sturdy structures and simple equipment. Hydro plants are dependable and long-lived, and their maintenance costs are low compared to coal or nuclear plants.

One requirement may increase hydropower's costs in the future. The procedure for licensing a dam has become a lengthy and expensive process. Many environmental impact studies must be undertaken and as many as 13 state and federal agencies must be consulted. It takes anywhere from five to seven years to get a license to build a hydroelectric dam.

U.S. ELECTRICITY PRODUCTION



Hydropower and the Environment

Hydropower dams can cause several environmental problems, even though they burn no fuel. Damming rivers may destroy or disrupt wildlife and natural resources. Fish, for one, may no longer be able to swim upstream.

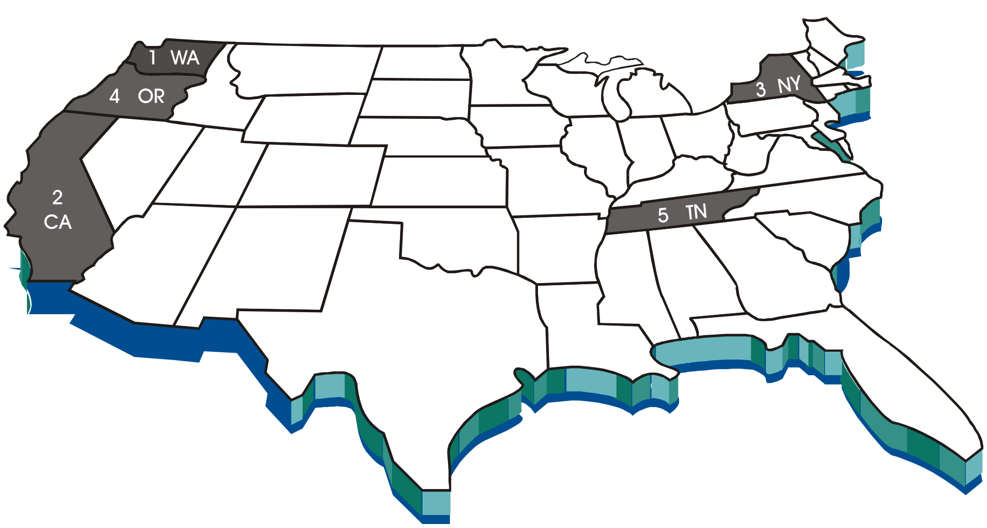
Hydro plant operations may also affect water quality by churning up dissolved metals that may have been deposited by industry long ago. Hydropower operations may increase silting, change water temperatures, and lower the levels of dissolved oxygen.

Some of these problems can be managed by constructing fish ladders, dredging the silt, and carefully regulating plant operations.

Hydropower has advantages, too. Hydropower's fuel supply (flowing water) is clean and is renewed yearly by snow and rainfall. Furthermore, hydro plants do not emit pollutants into the air, because they burn no fuel. With growing concern over greenhouse gas emissions and increased demand for electricity, hydropower may become more important in the future.

Hydropower facilities offer a range of additional benefits. Many dams are used to control flooding and regulate water supply, and reservoirs provide lakes for recreational purposes, such as boating and fishing.

TOP HYDROPOWER PRODUCING STATES



OTHER HYDRO*resources*

Tidal Energy

The tides rise and fall in eternal cycles. The waters of the oceans are in constant motion. We can use some of the ocean's energy, but most of it is out of reach. The problem isn't harnessing the energy as much as transporting it. Generating electricity in the middle of the ocean just doesn't make sense—there's no one there to use it. We can only use the energy near shore, where people need it.

Tidal energy is the most promising source of ocean energy for today and the near future. Tides are changes in the level of the oceans caused by the gravitational pull of the moon and sun, and the rotation of the earth. Near shore water levels can vary up to 40 feet, depending on the season and local factors. Only about 20 locations have good inlets and a large enough tidal range—about 10 feet—to produce energy economically.

Tidal energy plants capture the energy in the changing tides. A low dam, called a *barrage*, is built across an inlet. The barrage has one-way gates (*sluices*) that allow the incoming flood tide to pass into the inlet. When the tide turns, the water flows out of the inlet through huge turbines built into the barrage, producing electricity.

The oldest and largest tidal plant—La Rance in France—has been successfully producing electricity since 1968.

Today, the electricity from tidal plants costs more than from conventional power plants. It is very expensive and takes a long time to build the barrages, which can be several miles long. Also, tidal plants produce electricity less than half of the time. The seasons and cycles of the moon affect the level—and the energy—of the tides. The tides are very predictable, but not controllable.

On the other hand, the fuel is free and non-polluting, and the plants are easy to maintain. Only two operators are needed to run the La Rance plant at night and on week-ends. After they're built, the plants should run for a hundred years with little up-keep.

Tidal power is a renewable energy source. The plants do affect the environment, though they produce no air pollution. During construction, there are major short-term changes to the ecology of the inlet. Once the plants go into operation, there can be long-term changes to water levels and currents. The plants in operation have reported no major environmental problems.

The United States has no tidal plants and only a few sites where tidal energy could be produced economically. France, England, Canada and Russia have much more potential. The keys are to lower construction costs, increase output, and protect the environment.

Wave Energy

There is also tremendous energy in waves. Waves are caused by the wind blowing over the surface of the ocean. In many areas of the world, the wind blows with enough consistency and force to provide continuous waves. The west coasts of the United States and Europe and the coasts of Japan and New Zealand are good sites for harnessing wave energy.

There are several ways to harness wave energy. The motion of the waves can be used to push and pull air through a pipe. The air spins a turbine in the pipe, producing electricity. In Norway, a demonstration tower built into a cliff produces electricity for about four cents a kWh using this method. The wail of the fast-spinning turbines, however, can be heard for miles.

Another way to produce energy is to bend or focus the waves into a narrow channel, increasing their power and size. The waves then can be channeled into a catch basin, like tidal plants, or used directly to spin turbines.

There aren't any big commercial wave energy plants, but there are a few small ones. There are wave-energy devices that power the lights and whistles on buoys.

Small, on-shore sites have the best potential for the immediate future, especially if they can also be used to protect beaches and harbors. They could produce enough energy to power local communities. Japan, which must import almost all of its fuel, has an active wave-energy program.

OTEC

The energy from the sun heats the surface water of the ocean. In tropical regions, the surface water can be 40 or more degrees warmer than the deep water. This difference can be used to produce electricity.

Ocean Thermal Energy Conversion, OTEC, has the potential to produce more energy than tidal, wave, and wind energy combined. But, it is a technology for the future. There are no OTEC power plants in use today.

The warm surface water is turned into steam under pressure, or used to heat another fluid into a vapor. This steam or vapor spins a turbine to produce electricity. Pumps bring cold deep water to the surface through huge pipes. The cold water cools the steam or vapor, turning it back into liquid form, and the closed cycle begins again. In an open system design, the steam is turned into fresh water, and new surface water is added to the system.

An OTEC system is only about 2.5 percent efficient. Pumping the water is a giant engineering challenge. In addition, the electricity must be transported to land.

OTEC systems must have a temperature difference of at least 38 degrees Fahrenheit to operate. This limits OTEC's use to tropical regions where the surface waters are very warm. Hawaii, with its tropical climate, has experimented with OTEC systems since the 1970s.

Today, there are several experimental OTEC plants, but no big operations. It will probably be 15 to 20 years before the technology is available to produce energy economically from OTEC systems. OTEC will have the potential to produce non-polluting, renewable energy.